

# Detector Issues for Two Photon Physics

## at a High Energy Linear Collider

*Stephen R. Magill  
Argonne National Laboratory  
USA*

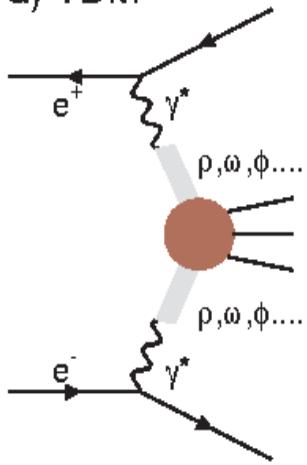
- Physics Processes (e<sup>+</sup>e<sup>-</sup> → e<sup>+</sup>e<sup>-</sup> + hadrons)
  - Forward Calorimetry at the LC
  - Beam Background Masking Scenarios
  - $\gamma^*\gamma^*$  Kinematics (Double Tags)
    - ⇒ Scattered e<sup>+</sup>e<sup>-</sup> Energy Measurement
    - ⇒  $Q^{**2}$  Measurement - Angular Segmentation
    - ⇒  $W\gamma^*\gamma^*$  and  $Y(=\ln(s/s_0))$  Measurements
    - ⇒ Summary of Measurement Comparisons
    - ⇒ BFKL Background Suppression
  - $\gamma^*\gamma$  Kinematics (Single Tags)
    - ⇒ Wvisible Measurement from Hadrons
    - ⇒ x Reconstruction from Wvis
    - ⇒ Low x Structure of the Photon
  - Conclusions
  - Future Plans

# Physics processes ( $e^+e^- \rightarrow e^+e^- + \text{hadrons}$ )

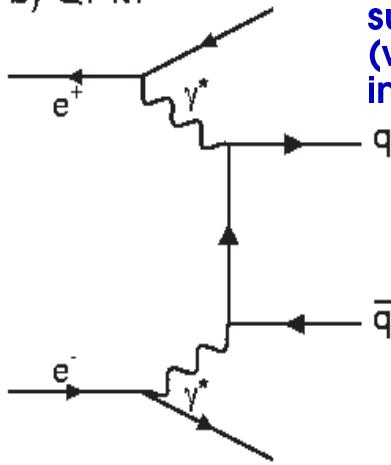
a) Vector - vector interactions  $\Rightarrow$  dominates 2-photon cross section for  $Q_{1,2}^{**2} \approx 0$

$\gamma\gamma$  collisions

a) VDM



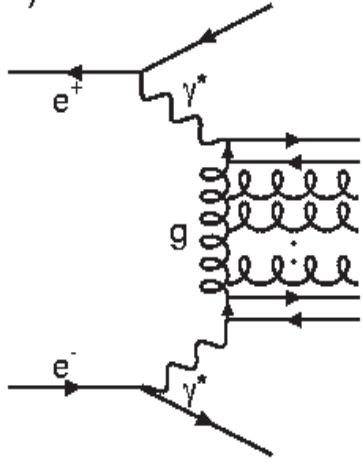
b) QPM



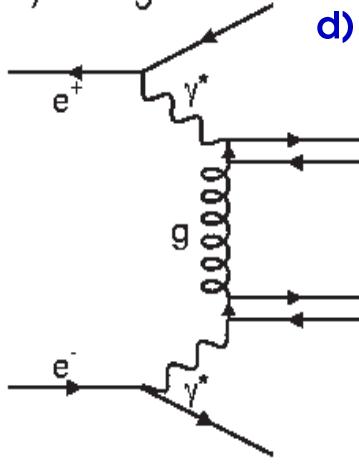
b) For increasing  $Q^{**2}$ , VDM is suppressed  $\Rightarrow$  QPM process (with QCD corrections) is important

$\gamma^*\gamma$  DIS  
for  $Q_1^{**2} \gg Q_2^{**2} \approx 0$

c) BFKL



d) one-gluon



d) BFKL "Born" process  $\Rightarrow$   
 $\ln(W_{\gamma\gamma}^{**2}/Q^{**2}) \sim 1$

$\gamma^*\gamma^*$  collisions

c) BFKL process  $\Rightarrow$  pQCD with 2 highly virtual photons,  $Q_1^{**2} \sim Q_2^{**2}$  to eliminate DGLAP evolution

Detection characteristics :

- 1) small angle  $e^+e^-$  scattering
- 2) hadronic activity

# Forward Calorimetry at the LC

- Scattered e+e- Tagging  
*EM calorimeter near beam pipe (fine-grained)*
- Hadronic W Measurement  
*EM + HAC (energy and position resolution)*

*Detector Studies :*

1) e+e- Tagging

*Perfect detector* ✓

*Cal position and energy resolution* ✓

*Backgrounds - e+e- pairs, etc.*

2) Wvis vs W

*Perfect detector* ✓

*Cal energy resolution* ✓



**Masking :**  
**Aggressive**  
vs  
**Conservative**

*Forward Tracking ( $\Delta p + \Delta x$ ) ?*

*Cal position resolution*

# Beam Background Masking Scenarios

## ● Aggressive Masking

**Outer Detector**      **> 55 mr**

**EMC** 15%/ $\sqrt{E} + 1\%$

**HAC**      **50% / √E + 3%**

**Mask** *30 -> 55 mr*

**EMC**       $25\%/\sqrt{E} \oplus 2\%$

**HAC**      **100%/ $\sqrt{E}$  + 5%**

## ● **Conservative Masking**

**Outer Detector** > 110 mr

**EMC**      **15% /  $\sqrt{E} + 1\%$**

**HAC**      **50%/ $\sqrt{E}$  + 3%**

**Mask** *80 -> 110 mr*

**EMC**      **25% / √E + 2%**

**HAC** 100%/ $\sqrt{E} \oplus 5\%$

**Inner Detector**      **30 -> 80 mr**

**EMC**      **15% /  $\sqrt{E} + 1\%$**

**HAC**      **75%/ $\sqrt{E}$  + 5%**

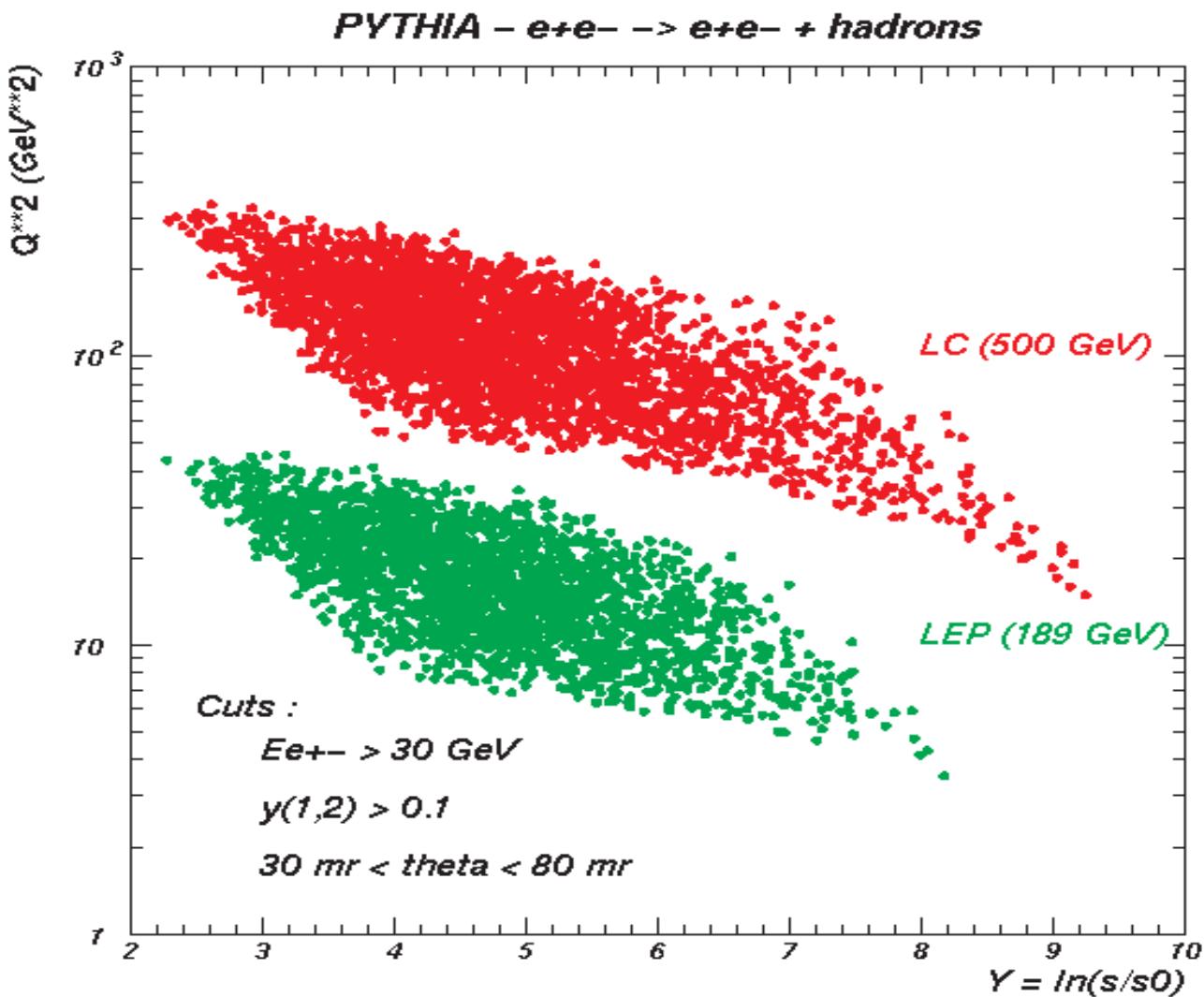
## $\gamma^*\gamma^*$ Kinematics

$$Q_{1,2}^2 = 2E_{\text{beam}} E_{1,2} (1 - \cos \theta_{1,2}) \approx E_{\text{beam}} E_{1,2} \theta_{1,2}^2$$

$$y_{1,2} = 1 - (E_{1,2}/E_b) * \cos^2(\theta_{1,2}/2) \quad \hat{s} = \hat{w}_{\gamma\gamma}^2 \approx s y_1 y_2$$

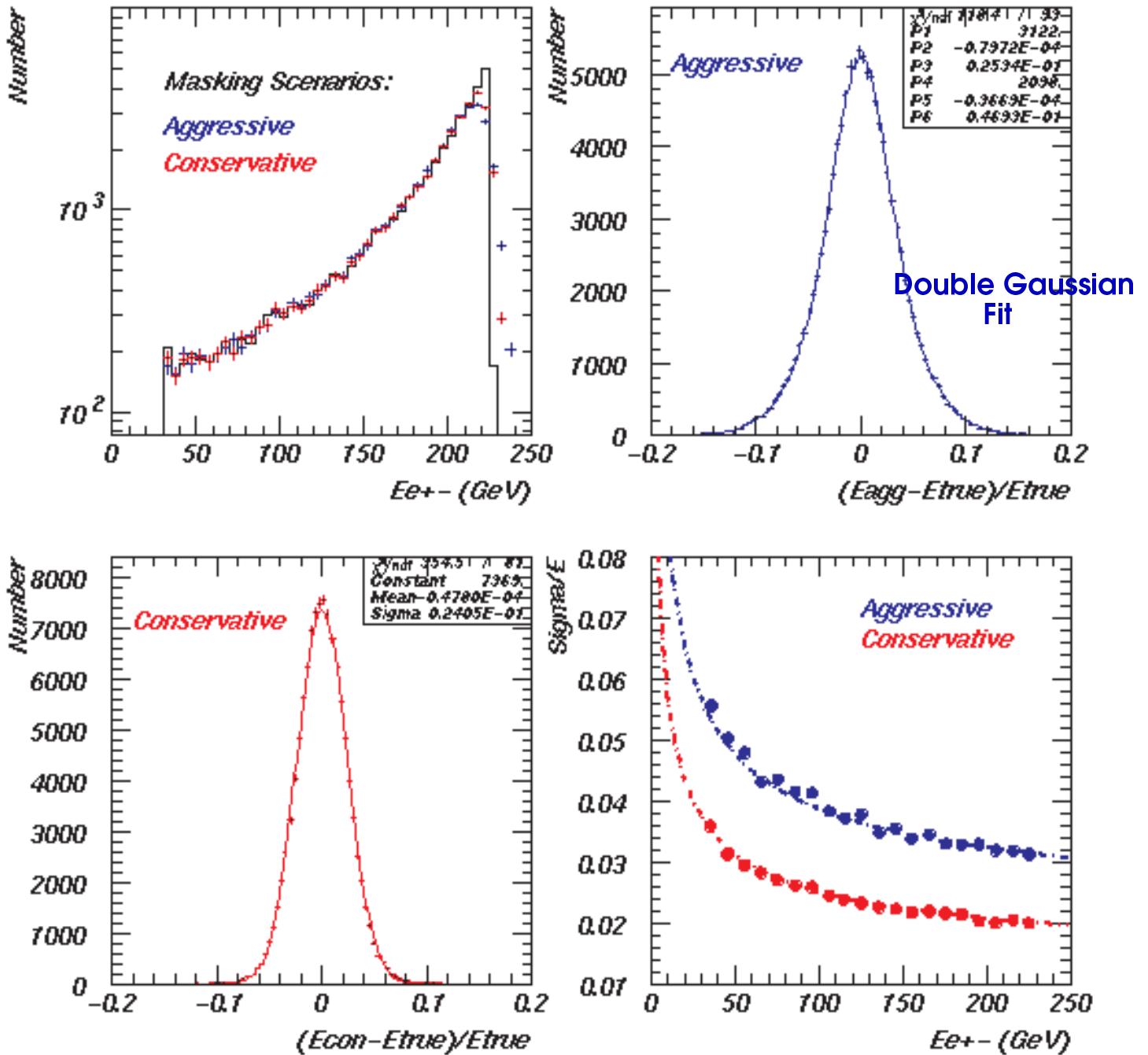
$$\sigma_{\gamma^*\gamma^*} = \frac{\sigma_0}{\sqrt{Q_1^2 Q_2^2 Y}} * \left( \frac{s}{s_0} \right)^{\alpha_p - 1} \approx \frac{\sigma_0}{\sqrt{Q_1^2 Q_2^2 Y}} * \left( \frac{\hat{s}}{\sqrt{Q_1^2 Q_2^2}} \right)^{\alpha_p - 1}$$

$$\sigma_0 = \text{const} \quad Y = \ln(s/s_0) \quad s_0 = \sqrt{Q_1^2 Q_2^2} / y_1 y_2$$



# Scattered e+e- Energy Measurement

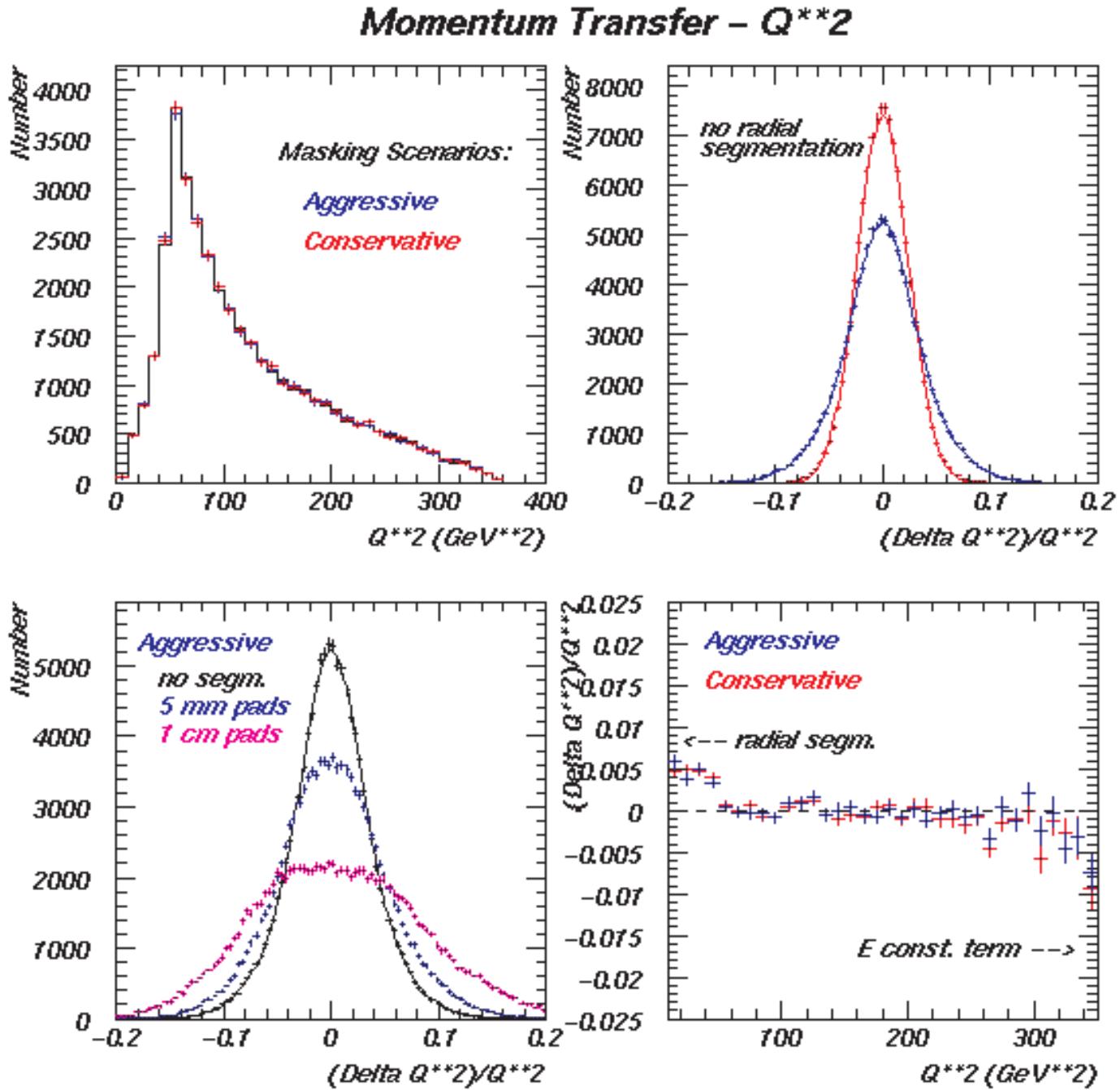
*Tagged e+e- Energy*



⇒ Check of smearing techniques

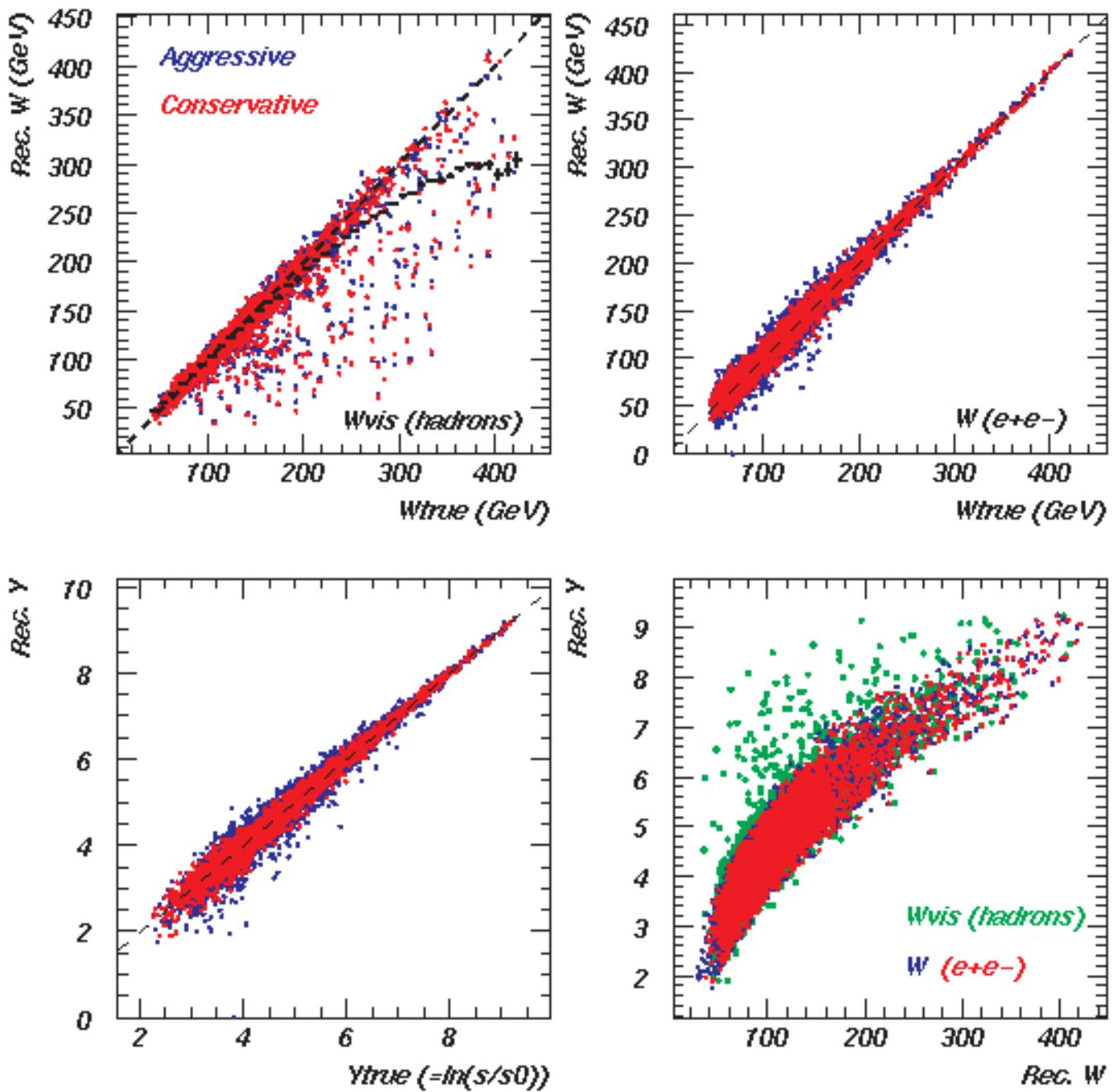
⇒ Small differences in  $E_{e^+e^-}$  between two scenarios

# $Q^{**2}$ Measurement - Angular Segmentation



- ⇒ Checks E resolutions
- ⇒ 5 mm radial pads (or less) very good
- ⇒ segmentation more important than E resolution, especially at low  $Q^{**2}$  ( $Q^{**2} \sim EE'\theta^{**2}$ )

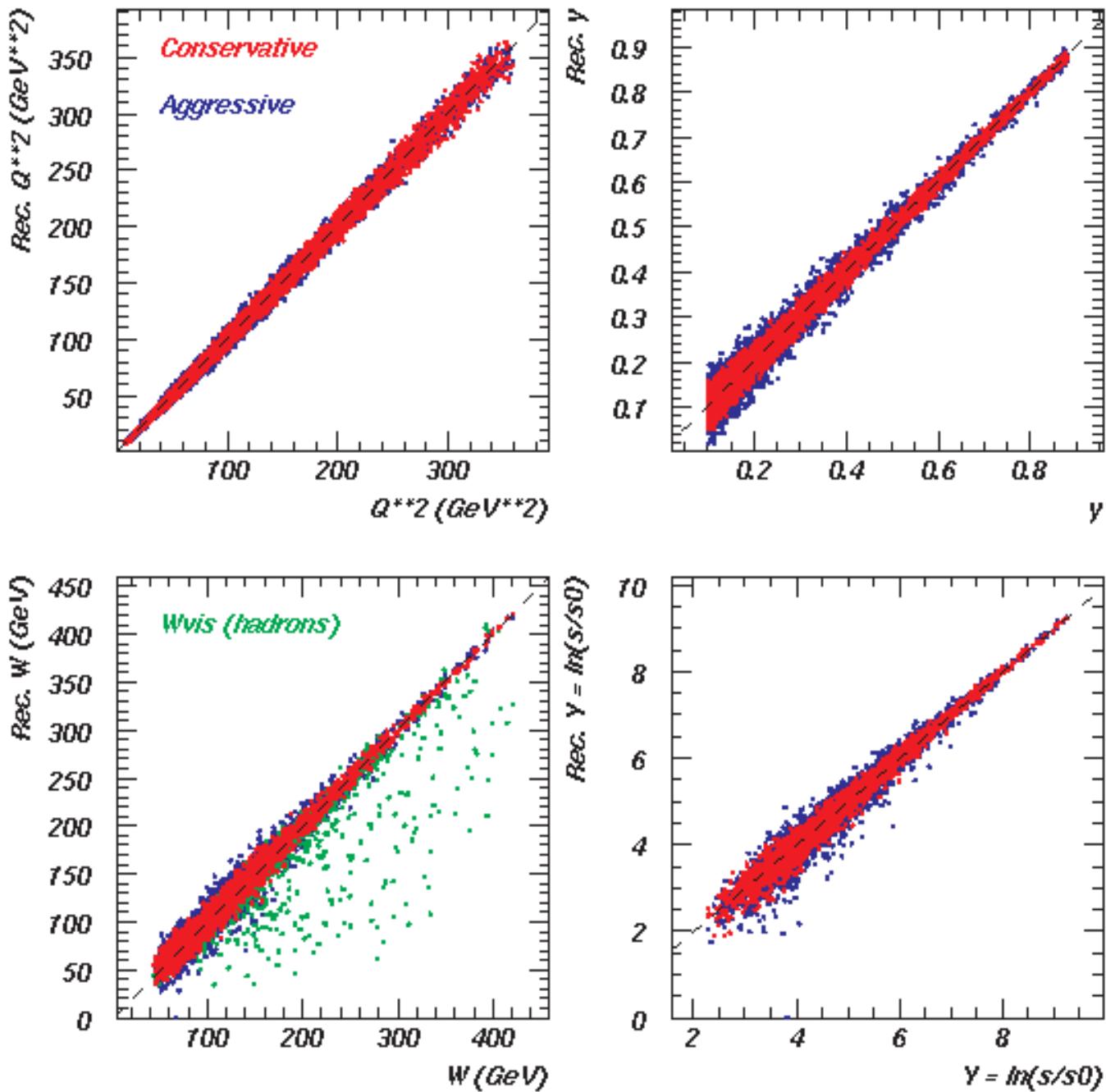
# $W\gamma^*\gamma^*$ and $Y(=\ln(s/s_0))$ Measurements



- ⇒  $W(e+e-)$  much better than  $W(\text{hadrons})$
- ⇒ poor  $W(\text{hadrons})$  reconstruction → large  $Y$  at low  $W$
- ⇒ **BUT -  $W(\text{hadrons})$  better here than  $\gamma^*\gamma^* \rightarrow$  later**

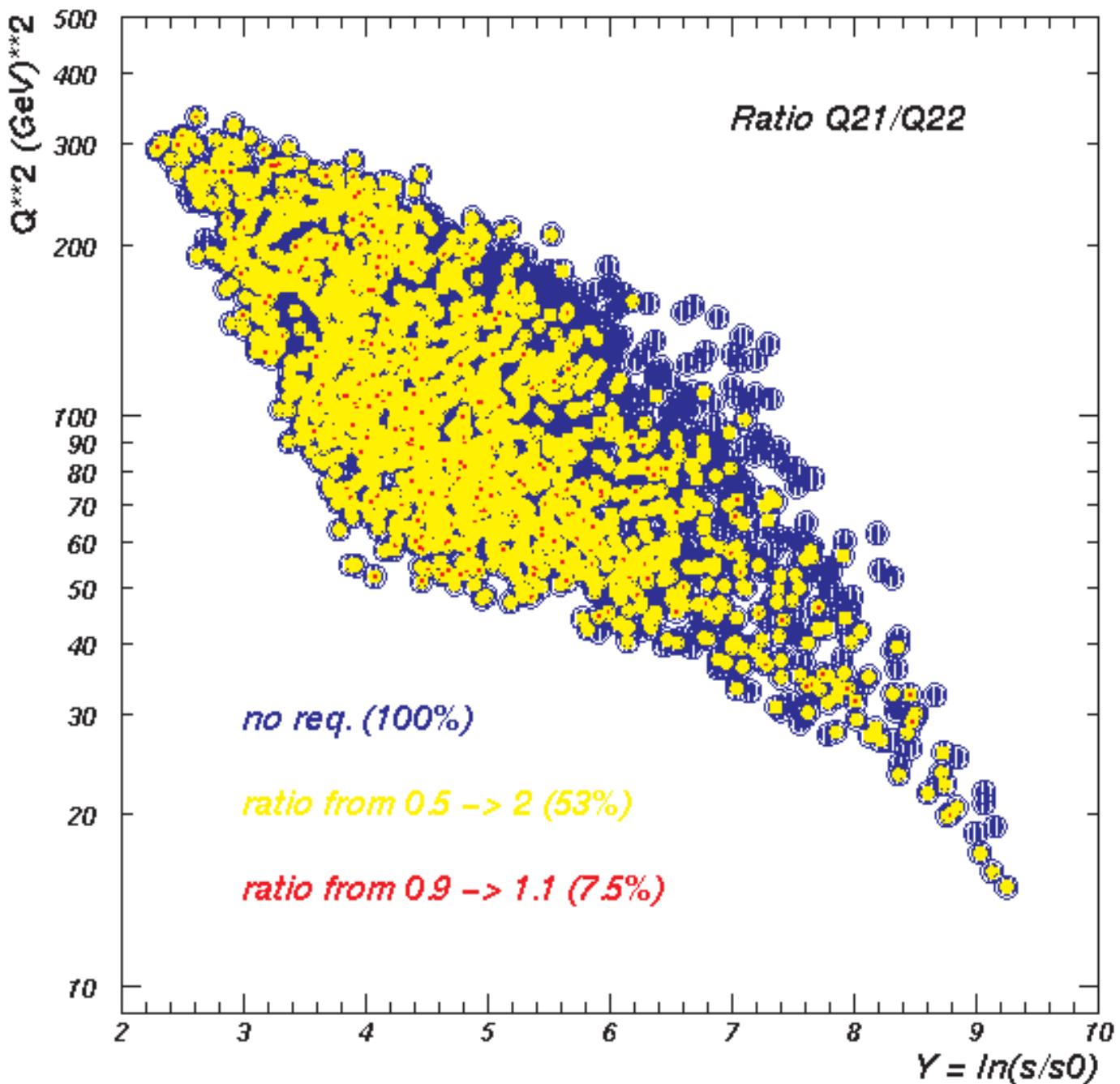
# Summary of Measurement Comparisons

*Double Tagged Kinematics Summary*



- ⇒ Very good reconstruction using tagged e+e- for both scenarios
- ⇒ Conservative masking scenario slightly better as expected

## BFKL Background Suppression



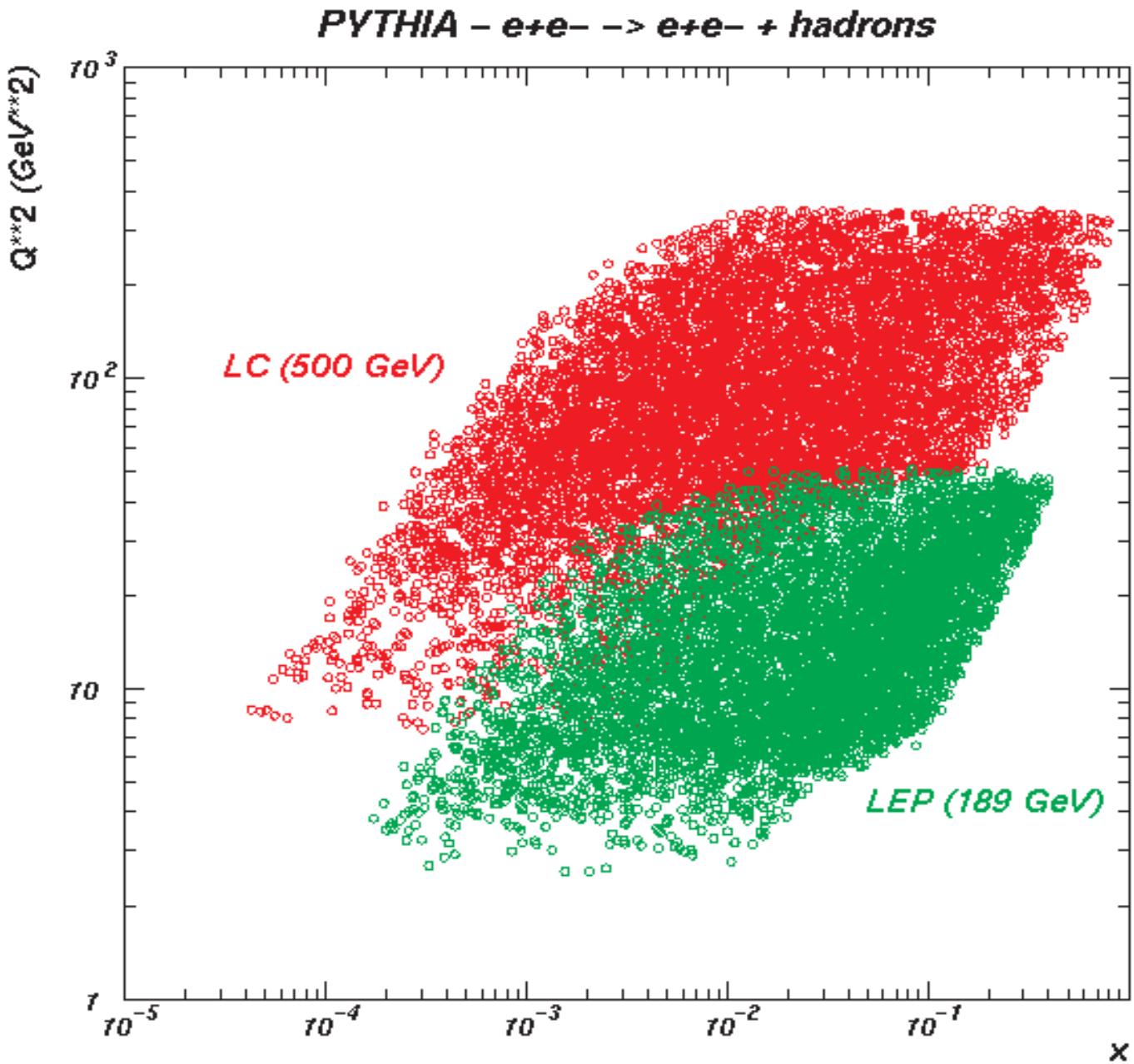
- ⇒ Requiring  $Q_1^{**2} \approx Q_2^{**2}$  reduces background to BFKL signal
- ⇒ Reduction factor of ~14 if  $0.9 < Q_1^{**2}/Q_2^{**2} < 1.1$

## $\gamma^*\gamma$ Kinematics

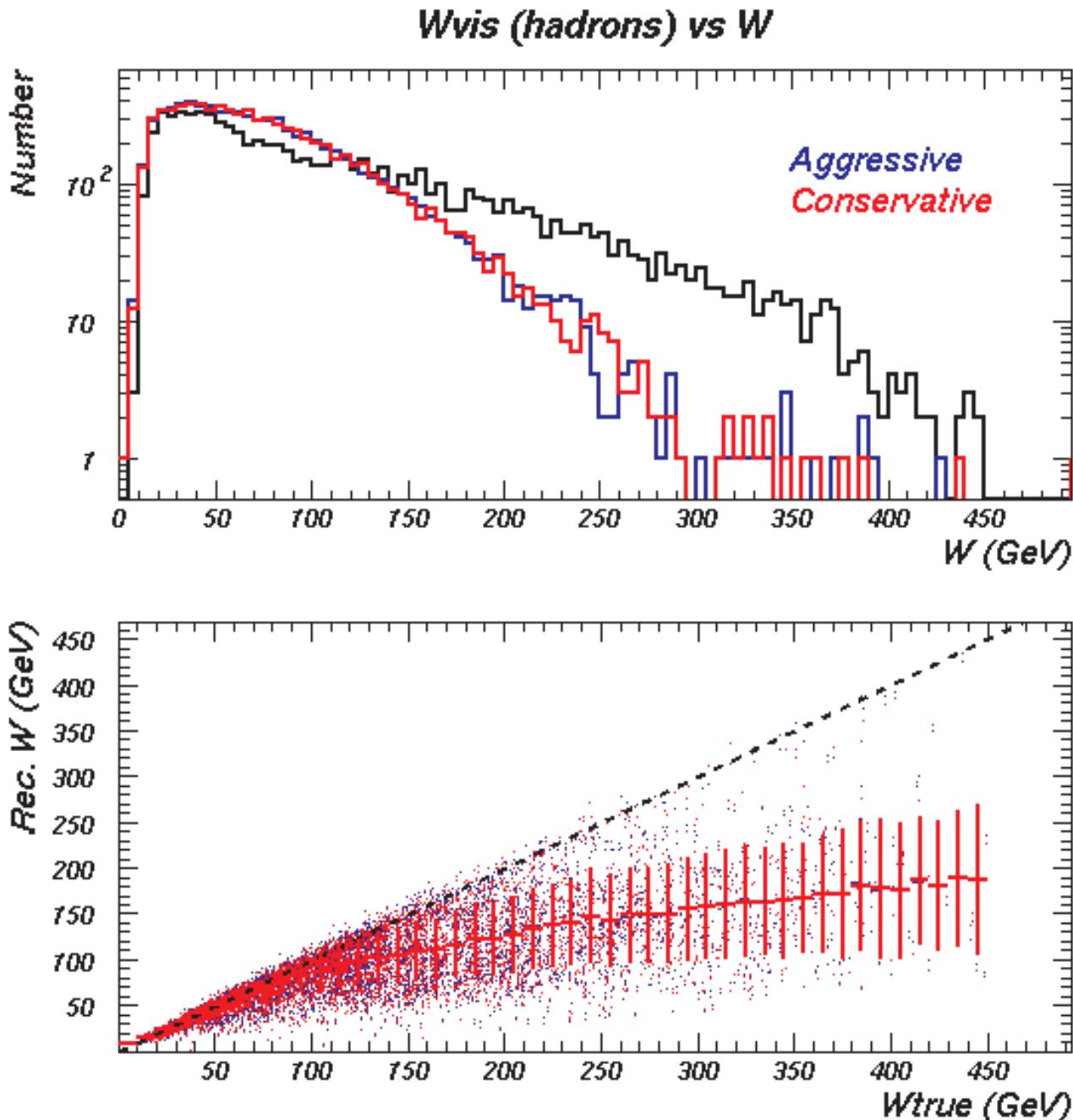
$$Q^2 = 2E_{\text{beam}} E_{\text{tag}} \left(1 - \cos\theta_{\text{tag}}\right) \approx E_{\text{beam}} E_{\text{tag}} \theta_{\text{tag}}^2$$

$$P^2 = 2E_{\text{beam}} E_{\text{untagged}} \left(1 - \cos\theta_{\text{untagged}}\right) \approx 0$$

$$y = 1 - \left(E_{\text{tag}}/E_{\text{beam}}\right) * \cos^2(\theta_{\text{tag}}/2) \quad x = \frac{Q^2}{Q^2 + W^2 + P^2}$$

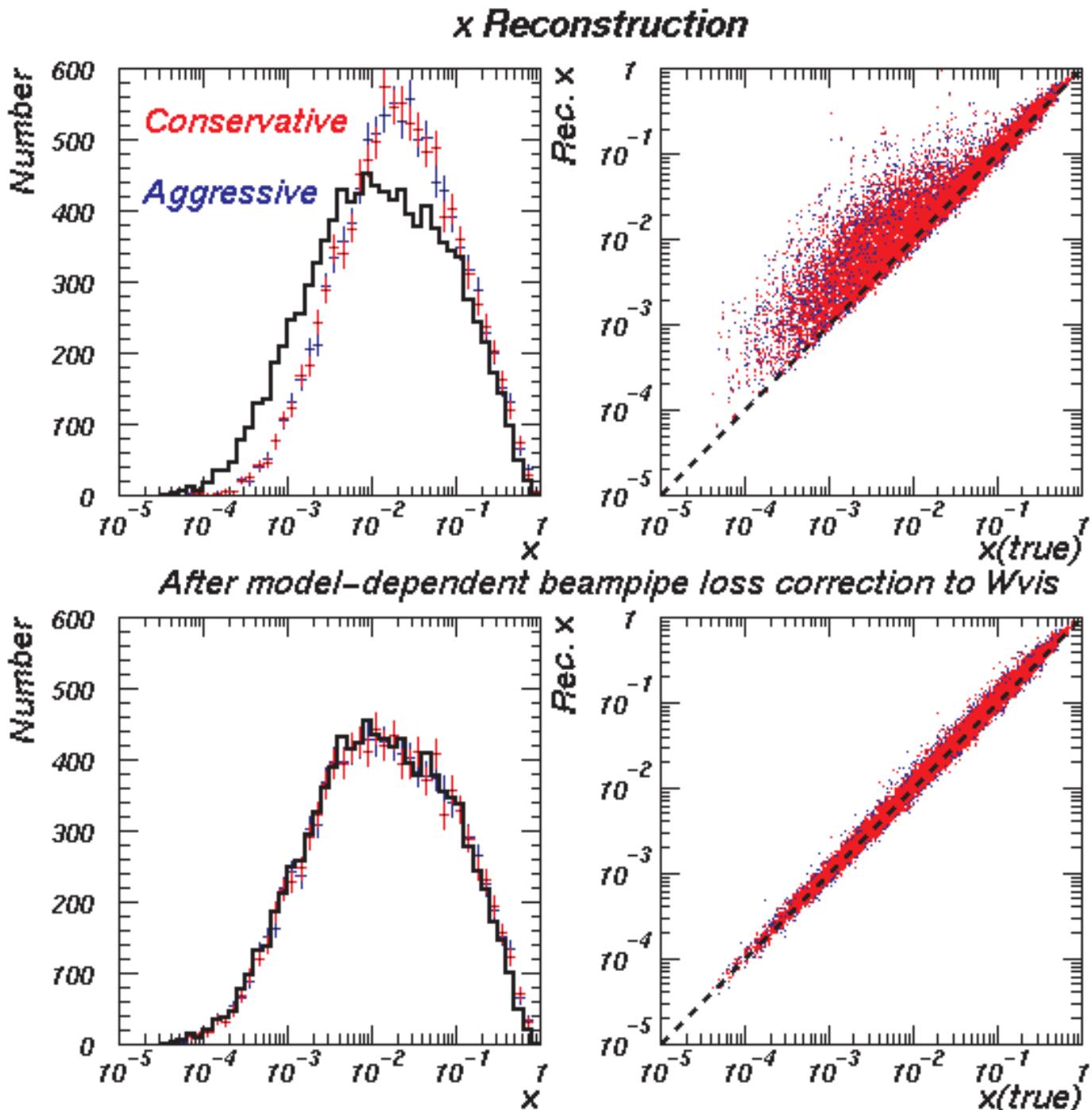


## W<sub>visible</sub> Measurement from Hadrons



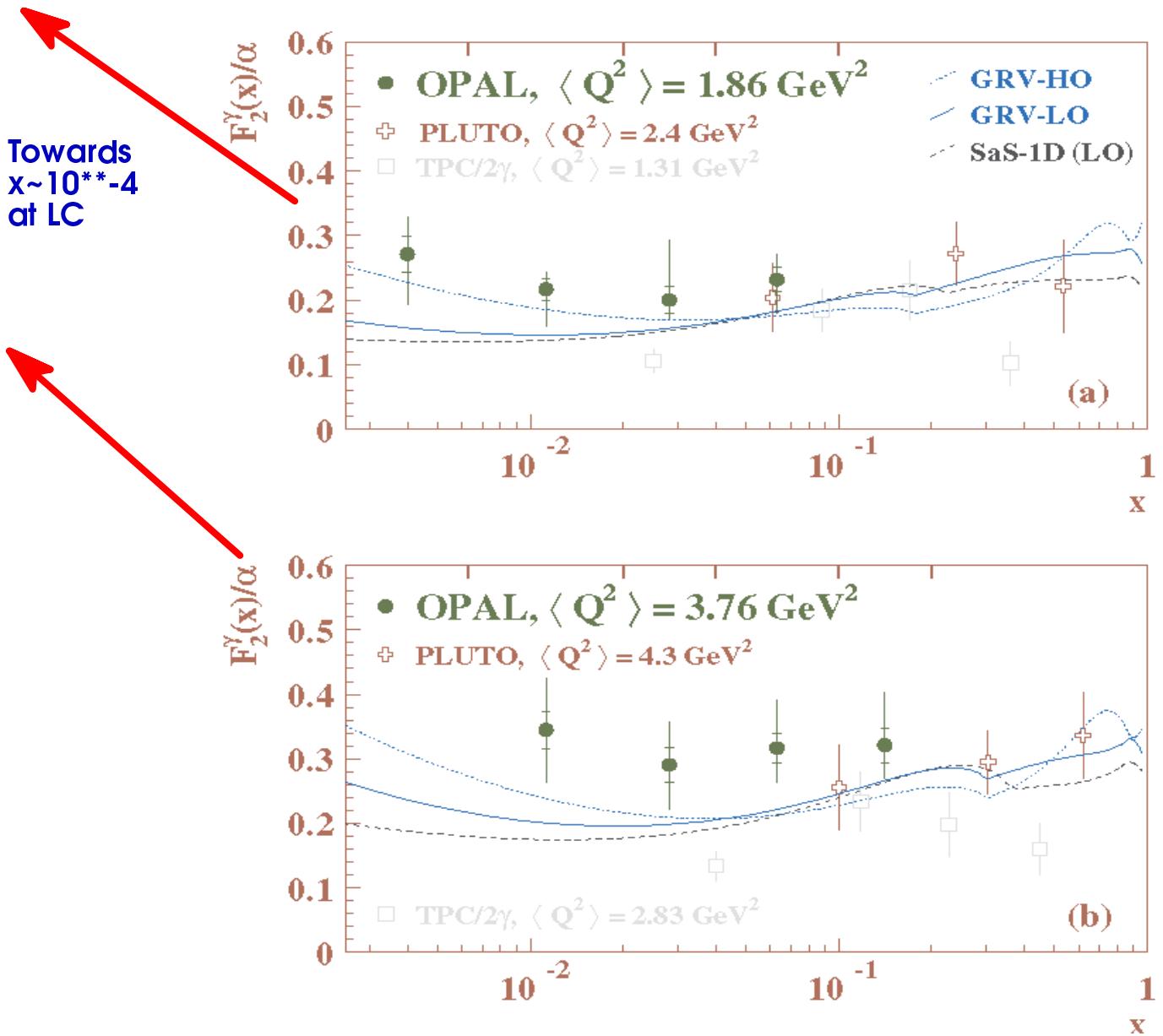
- ⇒ Significant loss of hadrons down beampipe -> due to boost ("target"  $\gamma$  mostly low energy)
- ⇒ Choice of masking scenario much less important than beampipe losses

## x Reconstruction from Wvis



- ⇒ Poor x reconstruction due to poor W measurement
- ⇒ Only OK after *model-dependent* correction to Wvis

# Low x Structure of the Photon



⇒ Large systematic error at low  $x$  from Wvis unfolding

⇒ Will a steep rise in  $F_2\gamma$  be observed at the LC?

→ better MC models

→ forward hadronic calorimetry

# Conclusions

- Double Tags :

- Best reconstruction of kinematic variables in  $\gamma^*\gamma^*$  events is obtained by measuring scattered e+e- parameters
- Energy resolution is secondary to good position resolution - 5 mm radial pad size (at least at electro-magnetic shower max) gives good reconstructed  $Q^{**2}$
- Both the Aggressive and Conservative masking scenarios are adequate to reconstruct  $\gamma^*\gamma^*$  events
- However, what is the effect at 30 mr of the  $\sim 10^{**5}$  e+e- pairs produced per bunch crossing by beamstrahlung?

- Single Tags :

- Again, reconstruction of kinematic variables from the tagged e+ or e- is good
- Again, choice of masking scenario is secondary to other issues . . .
- Requires observation of hadrons to reconstruct  $\gamma^*\gamma$  mass -> poor x reconstruction due to loss of hadrons in beampipe
- Need to rely ultimately on models to take full advantage of x reach of LC

# Future Plans

*Incorporate masking scenario with forward calorimetry (Conservative scenario preferred) into simulation package*

- ⇒ *Energy resolutions*
- ⇒ *transverse and longitudinal segmentation*
- ⇒ *clustering*

*Add (overlay) beam backgrounds to generated events*

*Improved Wvis (hadrons) reconstruction*

- ⇒ *reduce boost factor (laser backscattering)*
- ⇒ *mini-taggers around beampipe*